CRYPTOGRAPHY IN CREATIVE MEDIA

by

Olivia Grace Vanarthos

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Approved by:

Rick Klima, Ph.D., Thesis Director

Donna L. Lillian, Ph.D., Second Reader

Ted Zerucha, Ph.D., Interim Director, The Honors College

ABSTRACT

This paper argues the value of a creative approach to encryption. The first part of the text includes a survey of historical and modern examples of encryption in art, writing, and music to demonstrate the merit and purpose of cryptography in creative media. The second portion of the text relates an original musical method of encryption developed by the author. The purpose of this study and development is to identify and provide a creative solution to some musical cryptographic issues. There are many existing problems in other methods of musical encryption that have been produced to date. For example, they are easy to decrypt, are not well applied to long messages, or are too complicated to use for people who do not understand music well. This paper explains why the author's method is a unique and serviceable solution to these problems, using both visual and auditory examples.

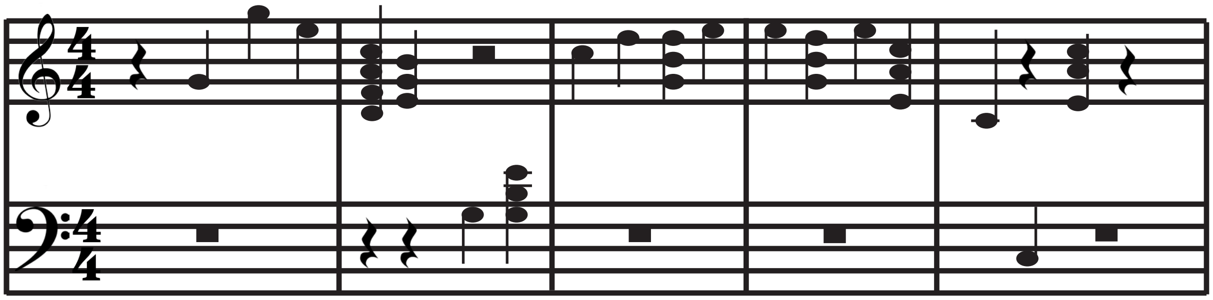


Figure 1.

INTRODUCTION

What does Figure 1 mean to you? Perhaps it looks like a boring shape exploration for a kindergarten art class. Or maybe, if you have had some musical experience, it looks like a standard sheet of uncomplicated music. But is something else going on here? Something lying within the structured gathering of quarter notes and rests?

The world of secret codes and hidden messages, wherein the answers to these questions lie, is called cryptography. Throughout the centuries, crypt analysts have been presented with puzzles that have grown more sophisticated over time. Now, in the digital age of infinite computing potential, codes have become so complex that analysts must derive technological, programmatic solutions to solve the most difficult ciphers that history has ever seen. Most ciphers can be solved through one's prior knowledge of typical, historical encryption methods. One must simply figure out how the old method is being applied in the new and complex technological format. But how would one solve a cipher without any context or similarities with which to analyze it? This is where crypt analysts struggle most: trying to solve a puzzle that was encrypted with a method that has never been seen before.

For this reason, some big advancements made in cryptography have been made by those who are able to think outside the box. Who better to do that than the world's creatives: the poets, the storytellers, the artists, and the musicians. The creatives are not focused on making the most complex cipher. Rather, they stretch the limits of what is possible. They invent. They change worldviews. They create experiences.

To best understand how cryptography has been advanced through creative media, one must first understand how ciphers are formed. A successfully transmitted message goes through four steps. First, the message, or plaintext, is encrypted (the method of encryption is called a cipher). Then, it must be sent and received. Finally, it must be decrypted; the result is called the "ciphertext," and how it is decrypted is called the "key." There are two polar avenues for using ciphers in creative media. The first is a plaintext message where no one can see it and only a few know where to look for it (plaintext encryption); the second is a ciphertext message where everyone can see it but only a few with the key know how to decrypt it (ciphertext encryption).

Plaintext encryption is often applied through the field and cryptographic style of steganography, a Greek word meaning covered writing. With steganography, the plaintext is left intact while its presence is concealed from any unintended recipients. Creativity dictates the effectiveness of steganography because the more abstract or unique the mode, the harder the message is to uncover.

One notable example of the second ciphertext method of encryption is a substitution cipher. A common cryptologic strategy, it has been found and applied in codes throughout the centuries. In a substitution cipher, units of the plaintext are replaced with characters of the ciphertext. A few variations are Playfair ciphers, Vigenère ciphers, Morse Code, and Navajo code. Although substitution ciphers can be fairly easy to decrypt with a long enough message, some of these historical samples counteracted the simplicity by combining the substitution cipher with another unique element. The Navajo Code, for example, encrypted all messages two-fold: once through a substitution cipher and again through the little-known Navajo language. The fact that the Japanese didn't understand the Navajo language prevented them from being able to crypt-analyze it and made it a very functional code.

Cryptograms, a type of puzzle often published in a newspaper, are another type of substitution cipher. Each number arbitrarily stands for a letter as shown below, and the crypt analyst must use their knowledge of basic linguistics to analyze the context and possible letter combinations (Crypto).

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
								19										22	8						

__	__	__	__	T	I	__	I	T	__		I	S		__	__	__	T	__	__	I	__	__	S ,
20	26	21	4	8	19	17	19	8	12		19	22		20	25	24	8	4	3	19	25	16	22

__	__	S	S		I	T		__	__ .		-		__	__	__	__	__	T	
11	4	22	22		19	8		25	24				4	18	23	21	26	8	

__	I	__	S	T	__	I	__
21	19	24	22	8	21	19	24

Figure 2. Cryptogram

In this example, there are a few two letter words, so “I,” “T,” and “S” are hypothesized in hopes that they might reveal some context to the other words. (Answers can be found on the last page of this text.) The types of characters that are substituted for the plaintext can take almost any form and are practically limitless. In fact, the piece of music that introduced this paper is actually a substitution cipher.

ART

The oldest known creative cryptography is steganography applied through art. One of the earliest recorded uses of steganography was by Histiaeus in 499 B.C. Wartime provides a strong need for creative steno-graphic tactics to gain the upper edge on one’s opponent. Histiaeus needed to send a message to Aristagoras in a plot to revolt against the Persians. Histiaeus shaved the head of his most trusted servant, tattooed the message onto his scalp, then waited for the slave’s hair to grow back before sending him to deliver the message to Aristagoras. Once the slave arrived, his head was again shaved. Aristagoras decided to follow the tattooed message's suggestion to revolt against Persia and attack Sardis (F. Bauer).

Another Ancient Greek example of steganography motivated by war was Demaratus in 480 B.C. Demaratus discovered the plans for an attack on his Grecian homeland by Persia, where he was exiled. The usual way for sending long distance messages was by inscribing them onto wax tablets, but if the Persians read the tablet, Demaratus would be discovered as an informer. So, with much ingenuity, Demaratus removed the wax from the tablet, carved the message into the base underneath, and resurfaced the tablet with a fresh layer of wax. As the message traveled to Greece, it appeared to everyone to be just a blank tablet, and, once decrypted, ultimately served to help Sparta prepare for an attack that would have otherwise been a complete surprise and a definite victory (Stanoyevitch 100).


Figure 3. Ancient Wax Tablet

Wartime has also prompted other steganographic encryption, like the invention of invisible ink. During the Revolutionary War, physicist and patriot James Jay "developed a sympathetic ink to communicate secret military information back to his brother in America." He even used the ink to tell Benjamin Franklin and Silas Deane about an intended British invasion that would come down from Canada (Macrakis 86).

Steganography has proved to be an exceedingly helpful historical tactic. But it has even deeper applications than just tattooing or invisible ink. Through deep, creative thought, steganography has even been combined with ciphertext encryption to dramatically further the secrecy of a message.

One of the most famous substitution ciphers is Morse code. It is so well known that it can be decrypted by anyone, but that doesn't mean

Figure 4. Morse Code Knitted into Clothing

that it can't be useful in encryption. In 1945, a cryptographer stitched the dots and dashes of Morse code through yarn and then used the yarn to knit an article of clothing that a courier wore. The fact that the key for Morse code is widely known actually aided the function of the encryption method; once the method was known, it was easy to decrypt, but it was remarkably enigmatic to discover in the first place.

During the French Revolution, a woman named Madame Defarge used this method to pass secret messages. Although many are now aware of this method and there are even tutorials online of how to construct a message with knit yarn, the creativity of the method still renders it hard to detect if one does not know to look for it.

WRITING

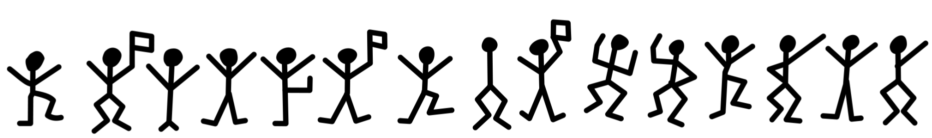
Beyond just art and steganography, plaintext encryption can also be found in creative writing. To add extra meaning into their work, the author places a secret message, like the name of a person the piece is dedicated to, within the structure of the writing. Famous American writer Edgar Allan Poe conceals the muse of his poems “An Engima” and “A Valentine” with a simple pattern. The first letter of the first line is taken. It is written in conjunction with the second letter from the second line, the third letter from the third line, and so on. The letters are underlined below in “An Enigma,” revealing his inspiration, Sarah Anna Lewis.

“Seldom we find,” says Solomon Don Dunce,
“Half an idea in the profoundest sonnet:
Through all the flimsy things we see at once,
As easily as through a Naples’ bonnet ––
Trash of all trash –– how can a lady don it?
Yet heavier far than your Petrarchan stuff ––
Owl-downy nonsense, that the faintest puff
Twirls into trunk-paper the while you con it.”
And, veritably, Sol is right enough:
The general tuckermanities are arrant
Bubbles ephemeral and so transparent;
But this is now –– you may depend upon it ––
Stable, opaque, immortal –– all by dint

Of the dear names that lie concealed within't.

"The Valentine" is constructed in the same fashion, secretly reading Frances Sargent Osgood, the object of Poe's affection. The tone is formal and passionate, and the incorporation of her name in every line deepens the romance of the poetry. But Poe was motivated to encrypt her name by more than just compositional creativity. Frances was married, and his fascination and love for her were societally impermissible. Serving dual purposes, Poe's clever encryption gains merit for his work and proves to his readers the profundity and quality of his writings.

Ciphers have also been written into the story lines of famous works, where the author describes the discovery and visual aspects of a cipher, and the reader is encouraged to solve it along with the characters in the story. When formed, they must be constructed in a way that is difficult to decrypt because everyone is immediately aware that the cipher exists. Arthur Conan Doyle, creator of "the most famous man that never lived" Sherlock Holmes, builds one Holmes' adventure around a substitution cipher. The story is titled "The Adventures of the Dancing Men" after the characters in the cipher. When the reader first comes into contact with the cipher in the story, all they see is the curious collection of men below, presented as another clue.



Over the course of the adventure, Holmes deduces that the men must have a systematic meaning and, as more samples of the cipher are revealed, uses the statistics of letter frequency, trial and error, and context to solve the riddle. Doyle's use of dancing men emphasizes and supports the idea that the replacement characters of substitution ciphers come in all shapes and sizes (C. Bauer 20).

Some written ciphers have yet to be decrypted. The three ciphers created by Thomas Beale are an example. They contain a much more valuable secret than a simple love affair. Only the first has been deciphered, and it says,

> "I have deposited in the county of Bedford, about four miles from Buford's, in an excavation or vault six feet below the surface of the ground, the following articles: … The deposit consists of two thousand nine hundred and twenty one pounds of gold and five thousand one hundred pounds of silver; also jewels, obtained in St. Louis in exchange for silver to save transportation."

Today, this is estimated at ten million pounds. But no one has yet retrieved the treasure because the second and third ciphers are still unsolved. They are all a series of numbers. The first starts with "115, 73, 24, 807, 37, …" and each corresponds to the first letter of a word in the Declaration of Independence. The 115th word in the Declaration is "institution," so the message begins with "I." Unfortunately, the next two are not encrypted with the same text, and maybe not even in the same substitutionary fashion, making the solution one of the most evasive and coveted in history ("The Beale Treasure Ciphers").

MUSIC

As seen above in the "Dancing Men," numbers and symbols can replace the plaintext in substitution ciphers. Music ciphers follow this same pattern. Instead of substituting a letter for a different letter, a letter is substituted with a musical note.

Many notable Classical musicians were also cryptologists. Eighteenth century composer and musician Johann Sebastian Bach alludes to his father in his music by using the notes that are known in the Germanic musical scale to stand for B-A-C-H. He patterns these notes in specific places to artistically articulate ideas, like in the fourth fugue in his incomplete work, "The Art of the Fugue." His style of encryption is limiting because he can only symbolize letters that have a musical Germanic equivalent and to incorporate such notes so frequently can alter the integrity of the piece.

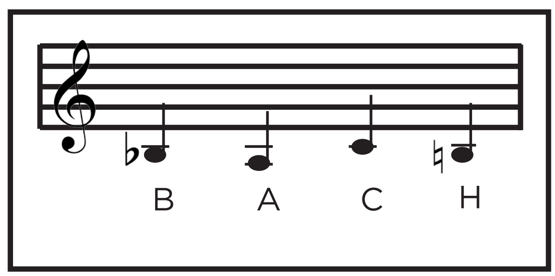


Figure 5. Bach Key

Alban Berg, another famous musician, implemented the idea of musical ciphers into a number of his works, encrypting the names of Arnold Schoenberg, Anton Webern, and himself. He also, like Poe, riddled his pieces with a series of references to his lover, Hanna Fuchs-Robettin, painting a “musical portrait” of her through tempos, textures, and rhythms (Bruhn 56-58).

Music naturally alludes to concepts deeper than what is noted on a page. Bach’s and Berg’s take this idea to a higher echelon; they combine the inherent transcendence of music with literal indirect references.

These composers make music an even more personal experience; their methods derived from sentimental or simple reasons. Despite their musical brilliance, the cryptographic keys are very easy to break. And although they are easy to use in a written format, if their cryptographic styles are applied to more complex messages, the music will sound uncoordinated and will be easily recognized as a false piece of music. Applying substitution ciphers to music was genius, but now we need a more universal method to take their idea a step beyond just encrypting names.

A few years ago, a few individuals from the Birla Institute of Technology developed a complete way to encrypt any information into music while maintaining the structure and sound. They account for everything from melodic intervals to rhythm rules; however, their method requires complex mathematical matrices and sequences that cannot be used by anyone who does not have a profound and holistic understanding of music (Kumar).

A NEW METHOD OF MUSICAL ENCRYPTION

From the flaws I found in current musical encryption, I developed a method of musical encryption that it is designed to make coherent sense as a piece of music and sound melodic, as well as be hard to crack if intercepted. My goals for the piece were to have an imperceptible cipher that is integrated into the music, a non-obvious but simple decryption method, and more than one solution for encryption while still being simple enough for anyone to apply it. As I explain how the method works, I will use the Key of C for my examples and tables.

My system is polyalphabetic; the music that stands for A, B, C, etc. changes depending on what key the sender chooses. Each letter is assigned both a specific note on the piano as well as a chord to make the code harder to break. The note and the chord have no correlation so fewer patterns can be detected. The notes and chords that are assigned to each letter must be in the chosen key's scale. This ensures that the music will sound good. The key is demonstrated by the number of sharps and flats written next to the time signature, as is typical in music. There are no sharps or flats seen in the example to the right, meaning that the music will be written in the Key of C.

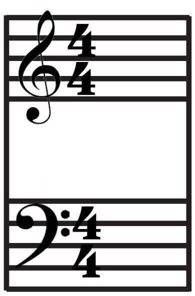


Figure 6. The Key

To begin assigning notes, one must find the base note of the key closest to Middle C and assign it to the letter "A," the first of the alphabet. The letters go alphabetically from left to right along the piano, skipping notes that are not in the chosen musical key. The alphabet starts on a note in the octave below Middle C, and that note is simply whatever the chosen

Figure 7. Assigning Letters to Notes in the Key of C

A	B	C	D	E	F	G	H	IJ	K	L	M	N	O	PQ	R	S	T	UV	WX	YZ
C	D	E	F	G	A	B	C	D	E	F	G	A	B	C	D	E	F	G	A	B

Octave 1 Octave 2 Octave 3

key is, so for my example, it starts at Middle C. All notes that are below the assigned "A" or above the assigned "Z" can be used as filler to make the music more complex and make the code harder to break. The letters and their corresponding musical notes in the Key of C are shown in the Table below. The letters are then assigned to unrelated chords in the key; the pattern for doing so is laid out below.

Figure 8. Assigning Letters to Chords

Chord	Major 1	Minor 2	Minor 3	Major 4	Major 5	Minor 6	Diminished 7
Regular	A	B	C	D	E	F	G
Seventh	H	I	J	K	L	M	N
Regular Inverted	O	P	Q	R	S	T	U
Seventh Inverted	V	W	X	Y	Z		

So for the Key of C, it would look like this.

Figure 9. Assigning Letters to Chords in the Key of C

Chord	C Major	D minor	E minor	F major	G Major	A minor	B Diminished
Regular	A	B	C	D	E	F	G
Seventh	H	I	J	K	L	M	N
Regular Inverted*	O	P	Q	R	S	T	U
Seventh Inverted*	V	W	X	Y	Z		

*Inverted means that the first note in the chord (D in D minor, E in E minor, etc.) is moved to the second, third, or fourth position in the chord. See the back for a visual model for how the chords look on the piano.

All notes and chords can be as long or as short as the person encrypting the message desires, depending on how the length influences the pleasantness of the sound. Trills, legatos, and other musical devices may also be included wherever the sender chooses, provided that the notes and chords within the alphabet are still distinguishable. Rests also play no part in the encrypting of the message, other than to act as another confusing element for a code breaker. Notes played in a triad still count as individual notes, even if connected by a top bar. If senders desire to add more types of characters, they simply need to agree with the recipient beforehand on which notes will stand for what and in which order, and go an octave higher.

The piece of music below was created using Figures 7 and 9. This is just one rendition of the message, "Music expresses that which cannot be put into words on that which it is impossible to be silent" by Victor Hugo.

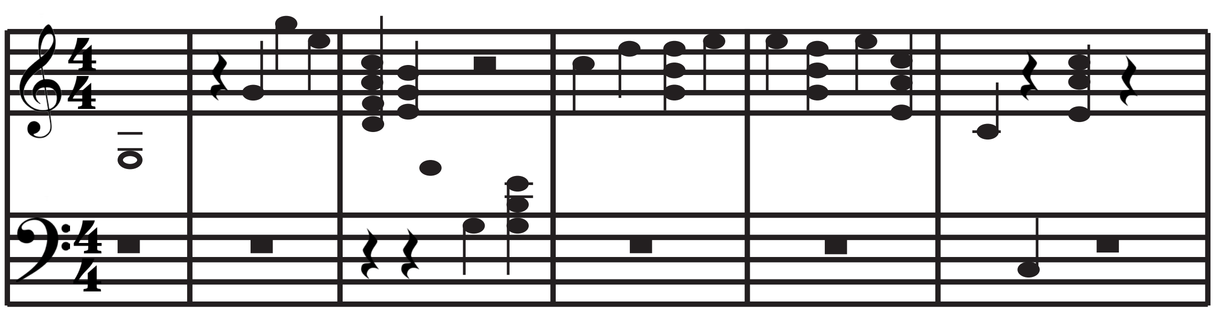


Figure 10. An Example of the Cipher (cont. on next page)

Figure 10. An Example of the Cipher

When we break down the first line, we can see how notes and chords are used to represent letters, and how the rests have no effect on the message.

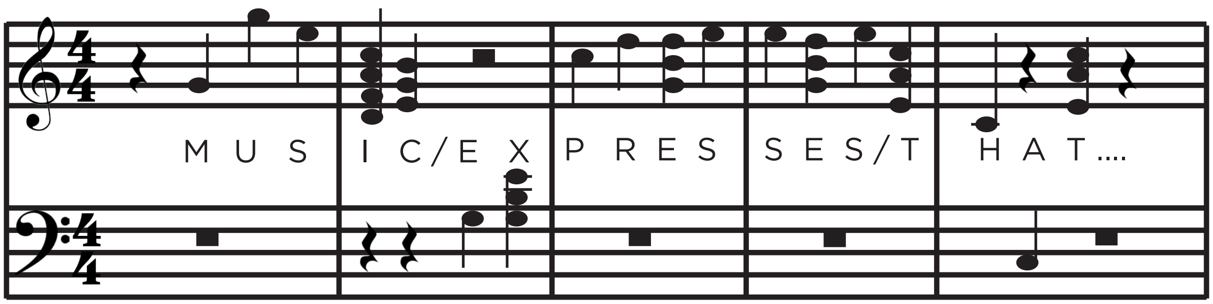


Figure 11. Breaking Down the Example

The musical file of what this piece sounds like to be played (including filler notes that make is even more gratifying to listen to) can be found at https://youtu.be/loOmCLbfGbs.

CONCLUSION

This new method serves to resolve issues that have previously existed in musical cryptography. It incorporates the two levels of encryptions that have made encryption in creative media successful through the ages; the first level of encryption is a substitution cipher, which makes it hard for someone to read the message, and the second is steganography, hiding the already encrypted message through pleasant sounding music so that no outside observer would know that there was a message present. Despite being heavily encrypted, it is still very user-friendly, with a simple key for decryption and no musical experience required. The combination of complexity and simplicity evident in this method make this a unique, creative, and effective solution.

Works Cited

Bauer, Craig P. Secret History: The Story of Cryptology. Boca Raton: CRC, 2013. Print.

Bauer, Friedrich L. Decrypted Secrets: Methods and Maxims of Cryptology. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007. Print.

Bruhn, Siglind. Encrypted Messages in Alban Berg's Music. New York: Rout ledge, 2011. Print.

"Crypto." Practical Cryptography. N.p., n.d. Web. 04 Apr. 2017.

Kumar, Chandan, Sandip Dutta, and Soubhi Chakraborty. Hiding Messages Using Musical Notes: A Fuzzy Logic Approach (2015): n. pag.Http://www.sersc.org/journals/IJSIA/vol9_no1_2015/23.pdf. Department of CSE, Birla Institute of Technology. Web.

Macrakis, Kristie. Prisoners, Lovers, & Spies: The Story of Invisible Ink from Herodotus to Al-Qaeda. New Haven: Yale UP, 2014. Print.

Reynolds, Christopher Alan. Motives for Allusion: Context and Content in Nineteenth-Century Music. Cambridge, MA: Harvard UP, 2003. Print.

Stanoyevitch, Alexander. Introduction to Cryptography with Mathematical Foundations and Computer Implementations. Boca Raton: Chapman & Hall/CRC, 2013. Print.

"Steganography." Merriam-Webster. Merriam-Webster, n.d. Web. 04 Apr. 2017.

“The Beale Treasure Ciphers.” The Guardian. 1999. Archived from the original on 2006-12-30. Retrieved 2017-04-14. https://web.archive.org/web/20061230080207/http://www.simonsingh.com:80/Beale_Treasure_Ciphers.html

Figures 1-2: Created by Author

Figure 3: https://natgeoeducationblog.files.wordpress.com/2016/06/mola-london-cursive.jpg?w=900

Figure 4: http://s838.photobucket.com/user/sartorialoftla/media/IMG_3137.jpg.html

Figures 5-11: Created by Author

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
4	23	20	10	21	9	3	14	19	2	15	18	7	24	25	11	5	26	22	8	16	17	6	1	12	13

C R E A T I V I T Y I S C O N T A G I O U S ,
20 26 21 4 8 19 17 19 8 12 19 22 20 25 24 8 4 3 19 25 16 22

P A S S I T O N . - A L B E R T
11 4 22 22 19 8 25 24 4 18 23 21 26 8

E I N S T E I N
21 19 24 22 8 21 19 24